Who benefits from the US withdrawal of the Kyoto Protocol? An application of the MMEA method to measure power

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Who benefits from the US withdrawal of the Kyoto protocol?*

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Abstract

Since 1992, the international community tries to reach a multilateral agreement on the reduction of gas emissions for greenhouse gases (GHG). A collective decision mechanism has been adopted in 1997 in Kyoto: An agreement is ratified if and only if it is approved by a coalition gathering more than 55 countries including industrialized countries (Annex I) that produce altogether at least 55% of the CO_2 of they emitted in 1990.

One way to study the a priori power distribution induced by this voting mechanism is to apply Shapley-Shubik and Banzhaf indices. In this paper, we compute these indices for each country. We show that the modifications generated by the European coalition scenario are significant. We also evaluate the influence of the United States withdrawal. Our conclusions are that the power distribution is largely heterogeneous, that the European policy counterbalanced the US leadership and that Japan and Russia benefited from the United States withdrawal (in term of a priori decisional power).

Key words: power indices, bargaining, environment, Kyoto protocol, empirical game theory.

JEL Classification: D71, Q20, C71.

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1 Introduction

In order to fight the Global Warming, the United Nations created a specific Convention in charge of reaching a multilateral agreement on the reduction of gas emissions for greenhouse gases. This convention, called the United Nations Framework Convention on Climate Change (UNFCCC) was established in June 1992 at the Rio Earth Summit. Its primary objective was the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (man-made) interference with the climate system". The UNFCCC is the governing body for international negotiations on the Global Warming.

In 1997, a collective decision mechanism has been adopted in Kyoto. The "Kyoto Protocol" could enter into force if it was ratified by at least 55 countries of the Convention, incorporating industrialized countries (Annex I[1]). Moreover, the ratifying countries from Annex I had to emit at least 55 per cent of the total CO_2 emissions in 1990 of the Annex I.

From the game theory point of view, the Kyoto Protocol can be considered as a simple game with a double-key or the conjunction of two weighted voting games. Most of the Developing Countries signed it because they had no emission constraint in the Kyoto Protocol. This protocol has been even ratified by more than 120 countries and the first quota of 55 participating countries is thus largely reached. For this reason, the first condition for ratification is neglected in our study. Consequently, We will focus on the second game where the voting weights only depend on CO_2 emissions.

Few countries produce the major part of the Annex I emissions (USA, Russia, Japan and Germany). The second quota has been thus difficult to reach due to the fact that the industrialized countries had emissions constraints. European countries agreed early to sign the protocol but tractations with the USA, Japan and Russia were long and hard. USA withdrew from the Convention in March 2001, Japan finally accepted to ratify the protocol in 2002. Russia announced in October 2004 that it was about to ratify it soon.

In order to explicit the theoretical influence of each country in Kyoto bargaining, we tried to estimate the distribution of the a priori decisional power induced by the voting mechanism, utilizing the Shapley-Shubik and Banzhaf indices. Thus, this paper adds to the growing literature on the applications of power indices to analyze the voting and decision schemes in several international bodies like EU [e.g., Machover (2004)], World Bank, IMF [e.g., Leech (2003)], etc.

Due to the large number of players, it is not possible to compute Shapley-Shubik and Banzhaf indices by direct enumeration techniques because of the exponential complexity of the model. Nevertheless, Dennis Leech suggested a method so-called "the Modified Multilinear Extension Approximation" (MMEA) for the games where most of the mandates are concentrated in the hands of a few players.

[1]See complete list in Table 1.

In this study, we present the Shapley-Shubik and Banzhaf indices and several methods to compute them. We analyze the a priori decision making power of each country of the Annex I using the MMEA method. We also consider the effect of the European alliances on the power distribution. Finally, we evaluate the consequences of the United-States withdrawal (March 2001).

2 Tools and methodology

We will present our analysis of the Kyoto negotiations through tools and concepts from the game theory. In fact, the study of voting power to a large extent was developed in close connection with the cooperative game theory. The aim of this section is to specify the tools which we will use and to introduce the elements of game theory which will be necessary.

Definitions and notations

The analysis of voting power is crucial in political science. The original idea of the study of this power is that the weight of a voter is not a good measure of its real influence. The real life example of voting body which reflects this reality concerns the first Council of the European Economic Community (1958-1973) gathering six countries (Germany, France, Italy, Belgium, the Netherlands and Luxembourg). In term of the voting weight, Luxembourg had one mandate, but it had no voting power at all as its approval was never necessary to reach a decision in the game structure [e.g., Straffin (1994)].

In general, it is difficult to define an exact measure of voting power. But mathematical power indices have been used for the special case of this power in the field of the cooperative game theory. A power index theoretically assigns to each player (voter) in a collective decision-making procedure a non-negative real number which indicates a player's ability to change the result of the game in favor of the option that it supports. This capacity is a player's power in a game, given the decision rules. Our study is devoted to the analysis of the a priori voting power which is defined as the probability of the different voters exert power when a decision has to be taken according to a given decision rule. The decision rule (quota or vote threshold) determines how many players' votes must be in favor of a proposal to guarantee its acceptance.

Historically, the first index was introduced in game theory literature[2] by Lloyd Shapley and Martin Shubik (1954). The original idea of this index was based on applying the Shapley value (1953) to the case of simple games. In their analysis, the authors introduced a voting scheme as well as the idea of being the decisive voter. A Decade later, another approach of measuring voting power was introduced

[2]Nowadays it is well known that Penrose (1946) had developed his own ideas on the measure of power and influence several years before. Unfortunately, his contributions have been ignored for a long time by the game theory community.

by Banzhaf (1965) which has been used in arguments in various legal proceedings. Many other indices were created, after that, while analyzing and by comparing Shapley-Shubik and Banzhaf indices.

The studies by the use of power indices is capital for two reasons. First, the indices enable us to analyze the decisional power distribution between the various parties of a collective decision-making procedure within a committee [e.g., Brams and Affuso (1976) and Coleman (1986)]. Thus, these indices have been intensively used to study the power within various national parliaments and international institutions considering a given decision rule. Secondly, they make it possible to evaluate the consequences on the changes in the decision rule [e.g., Lambert (1988), Felsenthal and Machover (1998)].

To present the power indices, we adopt the following notations. Let $N = \{1, ...n\}$ represents the set of n voters. A coalition S is the subset of N ($S \subseteq N$) and a weighted voting game[3] will be noted $G = \{q; w_1, w_2, ...w_n\}$ where $\{w_1, w_2, ..., w_n\}$ are the weights of the voters and q the quota. The players are ordered by their weight representing their respective number of mandates, so that $w_i \geq w_{i+1}$ for all i. The decision rule is defined by a quota, q, by which a coalition of players, S, is winning if $w(S) \geq q$ and losing if $w(S) < q$, where $w(S)$ is the sum of the weights of the players in S. A swing for player i is a pair of subsets $(S, S \cup i)$ such that S is losing but $S \cup i$ is winning. In terms of voting weight, S is a swing if $q - w_i \leq w(S) < q$. The set of all coalitions where $(S, S \cup i)$ is swing for player i is denoted by S_i and $Card\ S = s$.

The Shapley-Shubik (1954) index depends on the number of orderings in which each player is pivotal or swing. In fact, the justification of this index is as follows. We consider a group of individuals voting for or against a proposal (with yes or no). These individuals vote each one their turn. As soon as the quota was reached, the proposal is declared accepted and the person who voted last receives a "unit of the power" for having accepted it. If we suppose that all orderings of members are equally likely, we may estimate the average number of times where a given individual is pivotal.

Formally, the Shapley-Shubik index for game G is:

$$\phi_i(G) = \sum_{S_i} \frac{s!(n-1-s)!}{n!}$$

Banzhaf suggests an index with an aim to participate to resolve juridical debates concerning constitutionnel equity in electoral system representation. He justifies his index by arguing that in decision-making process the vote is not sequential: The coalitions vote in block. The power index depends on the number of ways in which each voter can affect a swing. In other words, it depends on the number of combinations, rather than on the number of permutations of players. The Banzhaf

[3]We restrict ourselves in this paper to the case of weighted voting games. For a more general definition, Felsenthal and Machover (1998).

score ($\sharp S_i$) of player i is consequently the number of possibles coalitions for which i is critical. The normalized Banzhaf index for player i is thus defined as following:

$$\beta_i = \frac{\sharp S_i}{\sum_{j=1}^{n} \sharp S_j}$$

Dubey and Shapley (1979) propose an other formula of Banzhaf score. The absolute Banzhaf index for player i is given by:

$$\beta_i^* = \sum_{S_i} \frac{1}{2^{n-1}} = \frac{\sharp S_i}{2^{n-1}}$$

One has to notice that $\beta_i^* \in [0,1]$ and gives the proportion of configurations of the $(n-1)$ other players where player i is swing.

Power index computations

Classical power indices can be computed with different methods. In order to evaluate power index when the number of player is large, several authors suggested different computation procedures.

Direct enumeration consists in applying directly the definition by seeking all the possible subsets and counting the pivotal (or critical) players. This method is only applicable to games including a small number of players because of its exponential complexity. This constitutes a major factor limiting the use of this technique.

Mann and Shapley (1960) used the **Monte Carlo simulation method** to estimate Shapley-Shubik index whenever the number of players is large. Wagner and Höhne (2001, p. 519) used this way to determine the power distribution due to the Kyoto decision mechanism for 34 players. However, Leech (2003) showed that results can be subject to sample error with this method.

Mann and Shapley (1962) suggested an alternative: the use of **the generating function**. This method gives exact results [e.g., Jimnez *et al* (2000)] and it is also a feasible method for games where the number of players is large. However, its limits are significant (storage requirements for integer sizes and array dimensions).

Another approach is based on Owen's researches (1972) concerning **the games multilinear extension** (due to Mann and Shapley). Owen employs the central limit theorem in order to approximate the expressions of the Shapley-Shubik index and the Banzhaf index. Results of multilinear extension method are exact; nevertheless, its complexity is the same as in direct enumeration.

The **multilinear extension approximation method**, founded on the central limit theorem, has a linear complexity [e.g., Owen (1995)]. The computation of these indices depends thus only on the number of players and the calculation of the statistical characteristics of the players weights distribution (mean and variance). But its accuracy depends on the validity of the normal approximation.

This technique can generate consequent errors of calculation if the weights are concentrated in the hands of some players.

Leech (2003, p. 833) suggests a combination between direct enumeration and multilinear extension approximation: **Modified Multilinear Extension Approximation (MMEA)**. This method is relevant for games where the number of player is too large for exact method and where the distribution of the weights is highly concentrated in the hands of a minority of players, which is the case for the Kyoto Protocol game.

Modified Multilinear Extension Approximation (MMEA)

The general procedure for computing the MMEA is based on the differentiation between *major players* and *minor players*. The set of the players, N, is divided into two subsets: $M = \{1, ..., m\}$, includes the major players with the largest weight and $N - M$ contains minors players. The choice of m is related to computing time. In fact, m has to be large enough to ensure accuracy without being too large to prevent all subsets of M to be enumerated in a reasonable computing time. The more m increases, the more computing time increases and errors become negligible.

The algorithm, proposed by Leech, searches all subsets of M. Given a particular subset, $S \subseteq M$, it evaluates the approximate conditional swing probability for each player making Owen's standard assumptions about random voting by minor players only, conditional on S.

Probability of a swing is obtained as the product of the probability of the formation of S and that of the conditional swing. The index is obtained by summing these joint probabilities over all the subsets.

3 Results

Power index computation is based on the parties included in the Annex I which is made up of 39 industrialized countries (see Table 1). However, the data of CO_2 emissions in 1990 are not available for Belarus. We computed thus the power index for 38 countries. Wagner and Höhne (2001) evaluated the power distribution within the parties of the Kyoto protocol (with the normalized Banzhaf index) for only 34 countries and neglected some countries in their analysis. This evaluation was carried out before the removal of Turkey from the Annex I (November 2001) which could have contributed to change the rule of the game. The power distribution can be strongly modified by these small changes. In addition, we reevaluate the power distribution through the computation of the Shapley-Shubik and the Banzhaf index (absolute and normalized), taking into account the removal of the Turkey. By all means, our results concerning the normalized Banzhaf index are very similar to theirs (slight differences also comes from updated data we used for the CO_2 emissions in 1990).

General results

Let G_1 represents the Kyoto game. The number of players is 38, and the quota is 0.55. The voting weights are distributed according to the emissions of the countries relative to the global emissions. We computed Shapley-Shubik and Banzhaf indices for 37 players with the generating function method and the MMEA ($m = 13$). Using appropriate parameters (choice of the set M), results are close with both methods.

Results of the distribution of the decisional power in the Kyoto Protocol are presented in Table 1. These results show that the power distribution is largely heterogeneous. By way of illustration, US's Banzhaf index is 50.84% whereas Russia's and France's Banzhaf index are respectively 9.24% and 2.28% (respectively 47.03%, 12.25% and 2.31% for the Shapley index).

But looking only at the normalized Banzhaf and Shapley-Shubik figures may be misleading when we want to analyze influence. The absolute Banzhaf index gives the proportion of the 2^{n-1} configurations, where the player can change the result. In fact, the more striking result is the absolute Banzhaf power of 0.8460 for the US. It shows that, a priori, the US had a decisive influence in about 85% of the configurations! In comparison, Russia's absolute Banzhaf index is a poor 15%.

Our results also permit to establish ratification conditions of the Kyoto Protocol. The presence of two countries is essential to the Kyoto protocol ratification. The United-States and Russia emit together 51.65% of CO_2 emissions of the Annex I. And their alliance could block any agreement. Therefore, if USA and Russia both refuse to enter into the negotiation, then the Protocol is doomed!

Except for the USA, all the countries of the Annex I have a lower power with the normalized indices than their weights in the voting mechanism. The weight of the USA, Russia and Japan are respectively 35.02%, 16.62% and 7.84% but their normalized Banzhaf index are respectively 50.84%, 9.24% and 6.51% (and respectively 47.03%, 12.25% and 6.76% for the Shapley index). Liechtenstein is even a dummy player in the Kyoto game and have actually no decisional power!

Even if the USA have the largest power, a few players have consequent power index (Russia, Japan, Germany). But this first analysis is quite misleading, as the countries of the European Union (EU15) played in a cooperative way during the Kyoto negotiations and had to be considered consequently as a unique player in the Kyoto game.

The European Union

The Kyoto negotiations was an important step forward toward the evolution of a common European position on environmental negotiations. The European countries adopted a cooperative behavior by convening before each Conference to combine their bargaining strategy. By adding their voices, European Union became a significant player in the Kyoto protocol game. The EU was also the only stable and relevant coalition since all European countries were included in the Annex I.

The formation of the European coalition changed the Kyoto game (called G_1 in section 1). In the modified Kyoto game, G_2, the set of players has changed: 15 countries combined their weights and became a single player "European Union". The set of players is composed of 25 players and the quota to be reached is the same as before (i.e. 55%). The only change in the distribution of the voting weight concerns the new player: the European coalition which accounts for 22.34% of the weights. Notice that we do not consider the countries that entered in EU in 2004 in this coalition.

Leech approximations are close to the direct enumeration results by choosing an well-suited set M. We computed Shapley-Shubik and Banzhaf indices for 25 players with both methods: The direct enumeration method and the MMEA ($m = 9$). In spite of the low number of players, results issued from the MMEA estimation are similar to those of the direct enumeration method. The results are displayed in Table 2.

This cooperative strategy enables the new player, EU15, to be ranked in the second place, in between the United States and Russia. The absolute Banzhaf power of EU15 is 0.3079, only slightly more than the sum of the influences its members alone. (0.3066). The European weight is 22.34% (it is exactly the sum of the European countries weights), nevertheless, the sum of their Shapley index and Banzhaf index were respectively 18.74% and 18.43% before the coalition. The European alliance made them increasing to 19.60% for the Shapley index and 18.44% for the Banzhaf index. At the first sight, the gain seems very slim and if we also take into account the internal decision scheme of the European Union, it may have been unadvantageous for members of the European Union to join this coalition[4]. However, the members of EU15 can be considered as very close in terms of their characteristics, and are used to work altogether and bargain among themselves. These are the true reason that ensure the stability of this coalition.

However, the creation of this alliance clearly reduced the influence of the USA. Their capacity to influence decreases for 0.846 to 0.692. The influence of the Japan also suffers from the formation of the EU coalition, curiously, their absolute Banzhaf index falls from 0.108 to 0.105. Other players benefit from the new rivalry between the two major players. Russia jumps from 0.154 to 0.292 for example.

The emergence of this second major player opens the game and makes it more difficult for the US to build up a coalition as they wish. It may be a key to understand the US withdrawal.

[4]Felsental and Machover (2004) explains clearly that, when two or more countries decide to form an alliance, the absolute Banzhaf power of a member of the alliance is the product of the power of the alliance times the power of the player inside the alliance. This last term of course depends upon the decision scheme that govern the alliance.

The US withdrawal

As the European coalition modified the Kyoto game by changing the set of players and the weights, the US withdrawal had a great influence on the Kyoto game and the a priori power distribution. In fact, the US withdrawal changed the game again! There is one less player and the CO_2 quota raised and the weights of the players were modified. In this new game, $G_3 = \{q', w'_1, w'_2, ..., w'_{24}\}$, the set of players accounted 24 countries, the quota to be reached was 84.65% ($q' = \frac{0.55}{1-0.3502}$). Again we used the MMEA technique (even if it was not necessary due to the small number of player) to obtain the results displayed in Table 3.

The consequences on the power distribution are multiple as the quota increased. The key point to understand the figures is that the high quota get the game close to the unanimity game. Thus, we should expect the power of big players to collapse and the influence of small players to increase (as they are more and more able to block the protocol). This is effectively what we observe in the figures: The distribution become more homogeneous.

The power of the European Union and Russia has decreased but Japan's power is enlarged. Even if, these two major players loose a power share, they always possess a theoretical power in the withdrawal cases. We also note that European alliance do not modify Russia's veto power. The three nations actually had the same influence, but they did not use it in the same way: The EU entered into a cooperative way whereas Japan and Russia decided to benefit from their new decisional power.

We notice that it appeared to be difficult to convince the biggest CO_2 emitters to ratify the protocol. USA is the most pollutant country, followed by the Russian Federation and Japan. Japan ratified the Kyoto protocol in return for new flexibility mechanism (June 2002) which increased its amount of permits. Russia obtained an agreement on the Carbon Sequestration before ratifying it. Finally, United-States withdrew the Kyoto protocol in March 2001. The difficulties of the protocol are calling the validity of the decision adopted in Kyoto in question.

At last, the US withdrawal can have had two effects for Japan and Russia [e.g., Carraro (2002)]. On one hand, Russia obtained an increasing decisional power. On the other hand, anticipated prices of emission permits on the permits market decreased while Russia was the biggest permits supplier. Russia lost thus on one side what it earned on the other side. Japan's situation is quite different: US withdrawal increased its decisional power. However, Japan have to acquire GHG permits to reach its emissions goal and the US withdrawal cut the price of the permits on the market. Its expected reduction cost thus decreased.

Conclusion

The objectives of this paper were twofold: From a technical point of view, we wanted to apply the recent technique of Leech (MMEA) to a game that has been seldom analyzed in the literature. This computation method has proved to be very useful to obtain good results in a short time. Secondly, we wanted to see whether the power indices could lead to a better understanding of the Kyoto protocol.

The decision-making process adopted in Kyoto in 1997 generates a highly heterogeneous distribution of the a priori decisional power and favors the countries with the highest CO_2 emissions. Furthermore, the major part of the decisional power is concentrated in the hands of few countries: USA, Russian Federation, European Union and Japan. The US theoretical influence is very large, they could have influenced the collective result in about 85% of the situations . Compared to the US demographic weight, US decisional power in Kyoto negotiations seems to be considerable. The United States represent 5% of the world population, 25% of the world emissions of greenhouse gases and more than 50% of the influence during the Kyoto negotiations!

This large decisional power, given to the industrialized countries was necessary to generate an effective agreement. To be efficient, the Kyoto agreement had to be ratified by the most pollutant countries and, in the same time, by the majority of the Developing Countries (which will be the most pollutant countries in the future). For this reason, Developing Countries did not have any emissions constraint and the decision rule was designed in order to give a large decisional power to the industrialized countries.

One could observe starting from the reports the Conferences of the Parties and by our results that the more a country has a large decisional power, the more it was difficult to make him ratify the protocol. Even if the EU, Russia and Japan had the same influence after the US withdrawal, they did not manage it in the same way. EU adopted a cooperative behavior whereas Japan and Russia benefited from their influence through new flexibility mechanisms. Our results suggest that Japan and Russia benefited from the US withdrawal, nevertheless, the expected price of the permits decreased with the US withdrawal. Russia is the largest permits supplier and Japan is the biggest permits seeker. It was a profit for Japan and a loss for Russia.

The decisional rule adopted in Kyoto does not seem to be relevant. Problems arise from the choice of countries CO_2 emissions as key parameters of the decision mechanism. Further researches should be undertaken considering another type of weights in the voting rule. For example, demographic weight should be tested.

To conclude, it seems difficult to judge on the Kyoto game. We guess that when it started in 1997, no expert could have been able to predict its final outcome. On one hand it has been rather successful, as the Kyoto protocol will probably enter into force soon. Moreover, it opens the way for new agreements in the future. On the other hand, the main polluter choose to withdraw. Retrospectively, it seems that the decisional power was not sufficient to impose its view, due to the EU15 approach.

Nevertheless, the computed power indices are theoretical measures of the decisional power given hypothesis. The reality of the Kyoto negotiations and the Russian attitude have shown us that linked problem (diplomatic, commercial and geostrategic) could save the Kyoto Protocol.

However, it is only the first part of the story. In 2007, the participant countries will meet to decide "how to decide" after 2012? During the Post Kyoto negotiations[5], another decision rule will be implemented in order to guarantee a efficient agreement. Again, the participation of the most developing countries will be necessary because they are the most pollutant and they have financial capacities. Furthermore, the participation of the Developing Countries will be required, consequently, the voting rule will have to take into account their importance by giving them a real decisional power. We will be confronted to the arbitration between the necessity of giving sufficient power to the industrialized countries and the necessary fairness to establish among the countries.

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Table 1: Estimation of the decisional power distribution between countries entered into the Kyoto Protocol.

Country	Emissions in 1990*	% CO_2	Shapley index	Banzhaf norm.	Absolute Banzhaf
USA	4 998 516	35.02%	47.03%	50.84%	0.8460
Russia	2 372 300	16.62%	12.25%	9.24%	0.1537
Japan	1 119 319	7.84%	6.76%	6.51%	0.1084
Germany	1 014 501	7.11%	6.09%	5.87%	0.0977
Ukraine	703 792	4.93%	4.14%	4.05%	0.0673
UK	583 705	4.09%	3.41%	3.38%	0.0562
Poland	476 625	3.34%	2.79%	2.75%	0.0458
Canada	471 563	3.30%	2.76%	2.72%	0.0453
Italy	439 478	3.08%	2.57%	2.54%	0.0422
France	394 067	2.76%	2.31%	2.28%	0.0379
Australia	277 867	1.95%	1.64%	1.61%	0.0269
Spain	227 233	1.59%	1.33%	1.31%	0.0218
Romania	194 826	1.37%	1.13%	1.13%	0.0187
Belgium	117 966	0.83%	0.68%	0.68%	0.0114
Bulgaria	103 856	0.73%	0.60%	0.60%	0.0100
Greece	84 336	0.59%	0.48%	0.49%	0.0081
Hungary	83 676	0.59%	0.48%	0.48%	0.0081
Finland	62 466	0.44%	0.36%	0.36%	0.0060
Austria	62 297	0.44%	0.36%	0.36%	0.0060
Slovakia	59 746	0.42%	0.34%	0.35%	0.0058
Sweden	56 065	0.39%	0.32%	0.32%	0.0054
Denmark	52 635	0.37%	0.30%	0.30%	0.0051
Portugal	44 109	0.31%	0.25%	0.26%	0.0042
Lithuania	39 535	0.28%	0.23%	0.23%	0.0038
Estonia	38 107	0.27%	0.22%	0.22%	0.0037
Norway	35 163	0.25%	0.20%	0.20%	0.0034
Ireland	31 599	0.22%	0.18%	0.18%	0.0030
New Zealand	25 267	0.18%	0.14%	0.15%	0.0024
Latvia	23 527	0.16%	0.13%	0.14%	0.0023
Croatia	23 305	0.16%	0.13%	0.13%	0.0022
Czech Rep.	16 399	0.11%	0.09%	0.09%	0.0016
Netherlands	15 963	0.11%	0.09%	0.09%	0.0015
Slovenia	13 935	0.10%	0.08%	0.08%	0.0013
Switzerland	4 442	0.03%	0.03%	0.02%	0.0004
Iceland	2 065	0.01%	0.01%	0.01%	0.0002
Luxembourg	1 275	0.01%	0.01%	0.01%	0.0001
Liechtenstein	195	ε	0.00%	0.00%	0.0000
Monaco	98	ε	0.00%	0.00%	0.0000
Belarus	N.A.	-	-	-	-

* See UNFCCC website GHG data base.
CO_2 emissions in Gigagrams.
N.A: Data Non Available

Table 2: Estimation of the decisional power distribution with the European coalition (EU15).

Country	Emissions in 1990	% CO_2	Banzhaf norm.	Shapley index	Absolute Banzhaf
USA	4 998 516	35.02%	41.44%	41.26%	0.6921
EU15	3 187 695	22.34%	18.44%	19.60%	0.3079
Russian	2 372 300	16.62%	17.47%	16.87%	0.2917
Japan	1 119 319	7.84%	6.26%	6.50%	0.1046
Ukraine	703 792	4.93%	4.39%	3.98%	0.0733
Poland	476 625	3.34%	2.96%	2.80%	0.0494
Canada	471 563	3.30%	2.93%	2.77%	0.0490
Australia	277 867	1.95%	1.83%	1.67%	0.0306
Romania	194 826	1.37%	1.20%	1.06%	0.0201
Bulgaria	103 856	0.73%	0.70%	0.54%	0.0116
Hungary	83 676	0.59%	0.55%	0.43%	0.0092
Slovakia	59 746	0.42%	0.39%	0.31%	0.0065
Lithuania	39 535	0.28%	0.26%	0.21%	0.0043
Estonia	38 107	0.27%	0.25%	0.20%	0.0041
Norway	35 163	0.25%	0.23%	0.19%	0.0038
New Zealand	25 267	0.18%	0.16%	0.13%	0.0027
Latvia	23 527	0.16%	0.15%	0.12%	0.0025
Croatia	23 305	0.16%	0.15%	0.12%	0.0025
Czech Rep.	16 399	0.11%	0.11%	0.09%	0.0018
Slovenia	13 935	0.10%	0.09%	0.08%	0.0015
Switzerland	4 442	0.03%	0.03%	0.03%	0.0005
Iceland	2 065	0.01%	0.01%	0.01%	0.0002
Liechtenstein	195	ε	0.00%	0.00%	0.0000
Monaco	98	ε	0.00%	0.00%	0.0000
Belarus	N.A.	-	-	-	-

Table 3: Distribution of the theoretical decisional power after the US withdrawal.

Country	% CO_2 in 1990	Shapley index	Banzhaf norm.	Absolute Banzhaf
EU15	34.37%	30.62%	20.96%	0.1529
Russia	25.58%	30.62%	20.96%	0.1529
Japan	12.07%	14.63%	19.11%	0.1395
Ukraine	7.59%	6.34%	10.95%	0.0799
Poland	5.14%	4.62%	6.85%	0.0500
Canada	5.09%	4.59%	6.80%	0.0496
Australia	3.00%	3.08%	4.05%	0.0295
Romania	2.10%	1.83%	3.08%	0.0225
Bulgaria	1.12%	0.80%	1.73%	0.0126
Hungary	0.90%	0.65%	1.28%	0.0093
Slovakia	0.64%	0.47%	0.91%	0.0066
Lithuania	0.43%	0.33%	0.60%	0.0043
Estonia	0.41%	0.32%	0.57%	0.0042
Norway	0.38%	0.30%	0.53%	0.0039
New Zealand	0.27%	0.20%	0.38%	0.0028
Latvia	0.25%	0.18%	0.35%	0.0026
Croatia	0.25%	0.18%	0.35%	0.0026
Czech Rep.	0.18%	0.13%	0.25%	0.0018
Slovenia	0.15%	0.11%	0.21%	0.0015
Switzerland	0.05%	0.04%	0.07%	0.0005
Iceland	0.02%	0.02%	0.03%	0.0002
Liechtenstein	ε	0.00%	0.00%	0.0000
Monaco	ε	0.00%	0.00%	0.0000
Belarus	N.A.	-	-	-